The Sidereal Messenger.

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory.

SEPTEMBER 1885.

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By faith we understand that the worlds have been framed by the word of God, so that which is seen hath not been made out of things which do appear.

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XUM

The Sidereal Messenger

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory, Northfield, Minnesota.

"In the present small treatise I set forth some matters of interest to all observers of natural phenomena to look at and consider."—GALILEO, *Sidereus Nuncius*, 1610.

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SMALL VS. LARGE TELESCOPES.

S. W. BURNHAM.

Much has been written recently in some of the astronomical journals, and more particularly in the *Observatory* by Mr. DENNING and others, on the comparative value of large and small apertures for showing planetary details and other faint celestial objects; and Mr. DENNING has expressed the opinion that "apertures of from six to eight inches seem able to compete with the most powerful instruments ever constructed." This novel view is based, to some extent at least, upon the failure of the Chicago 18½-inch refractor, in the hands of Prof. HOUGH, to show certain details on the surface of *Jupiter* alleged to have been heretofore seen by various observers with much smaller apertures, and also certain remarkable convulsions or changes on the surface of that planet which have been so frequently described by the possessors of portable telescopes. Prof. HOUGH, it should be noted, has specially studied this planet, and made micrometrical observations with this instrument on every available occasion during the last five years. The evidence of such changes usually consists in the inability to see a a spot or marking on one night which was quite obvious on some immediately preceding or following evening. The argu-

ment might have been extended in this direction by also citing numerous instances of double-stars alleged to have been discovered with small telescopes, and these discoveries verified by other observers, but which have persistently remained invisible in the refractor of the Dearborn Observatory and other large telescopes. At the time of the supposed discoveries such instances would have furnished an admirable text for a discourse on the advantage of the smaller instrument, though perhaps it is too late now to turn them to any account in that direction, since it would be difficult to find an astronomer who is not convinced that these observers, like many others since, were too hasty in rushing into print as discoverers, when, by a little patience, they could have satisfied themselves that they had really seen nothing at all. I have spent a good deal of time, first and last, which might have been better employed, in running down these tales of new stars. I had indeed, at the start, but little faith in their existence, partly because as a rule the observers had never discovered any real objects of that class which were difficult, and partly because the character of the instruments employed was such that it was in the highest degree improbable that even an experienced observer could see any companion stars of the magnitude and distance described which would be overlooked by the skilled observers who had traversed that field. In every instance — and there were many of them — I not only failed utterly to see these alleged stars, but satisfied myself by repeated trials under the most favorable conditions that they were purely imaginary. It never occurred to me that I was laboring under any disadvantage in using a larger aperture than those before employed, or that I could be mistaken in asserting positively, after a fair and thorough investigation with the aid of such an instrument, that the supposed stars were simply due to an excess of imagination on the part of the several writers. Perhaps, if I had not used the telescope in question for the discovery of some hundred of difficult pairs, and in the repeated examinations of the severest stellar and other tests

known, I might have had less confidence in my own eyes as well as the telescope. The experience I have had with other telescopes by the same makers, nearly as large and larger, leads me to have the same faith in them and their power to show anything which has been really seen elsewhere, that I have had for a long time in that at the Dearborn Observatory. That I have as much reason, perhaps, as any one to appreciate the value of small instruments, will be apparent from the work done with the 6-inch refractor, and for the further reason that the discoveries thus made will all be found to stand the test of future examination.

I have no doubt Mr. DENNING intends to deal with the subject fairly and impartially; but two things are apparent from his communications: First, that his statements are based wholly upon a comparison of small instruments with larger reflectors; and, second, that he has never worked with any first-class refracting telescope. Speaking of large apertures he says: "While possessing an immense superiority of light over smaller telescopes, they are rendered ineffective by inferior definition." This remark would certainly be absurd if intended to be applied to instruments of the quality of those made by ALVAN CLARK & SONS. If it relates to reflectors, as it probably does, most readers will agree with him throughout, and in the conclusion that the best definition is rarely, if ever, found in large reflectors. Personally, I have had no experience in using telescopes of this form, but judging from what has been done by the larger reflectors, and more particularly by what has not been done, in departments of work where the most perfect definition attainable is absolutely essential, the conclusion is irrestible that however well they may answer for work on nebulæ, for instance, where there is nothing to define, and where, from the absence of this quality, the picture and text are rendered all the more pleasing and original, or in any class of work where the result is principally descriptive they are immeasurably inferior to the refractors in work requiring sharp definition. In double-star work,

for example, no very close pair has ever been discovered by a large reflector, nor any pair which would be considered a test for the definition of such an aperture. As a matter of fact, practically all the difficult pairs which have any interest as double-stars have been discovered, and the measures of this class of stars made, with refracting telescopes; and this will continue to be the case until some radical improvement is made in the reflecting telescope. It is not enough to say that these observers did not wish to do that kind of work; for no observer, with a perfect instrument of twelve or fifteen inches aperture, and upwards, could fail to find something new among the double-stars, whatever field of work he might be engaged in. It would be almost impossible to avoid it, and most observers would not fail to mention it, even if their principal interest was in another direction. Let the possessor of such a reflector take a little pains to satisfy himself on this point, and spend an hour or two on some good night in the discovery of a *new* double-star with a distance of not more than 0″.3 or 0″.4, if the stars are about equal, or two or three times that distance if there is a difference of at least five magnitudes in the components. If his instrument is approximately equal to a CLARK refractor, it will not take him long to verify and prove it in the manner I have suggested; and such proof would almost necessarily be satisfactory to others as well. For this purpose, observations of known pairs are not satisfactory, for we all know how easy it is for many to fancy a thing is seen when it is known beforehand just how it looks, and where it is; and descriptions of how test doubles appear in the telescope are as unsuitable to enable others to judge of the performance of the instrument as descriptions of planets, and other observations which cannot be positively verified. This is not intended as a reflection on the good faith of any one, but it is not too much to say that the "scientific use of the imagination" is brought into exercise as often in astronomical writings as in any other papers. If some one will point out any hitherto unknown close

component of a star, using any reflector, however large, or a telescope of any form under 18½-inches aperture, which we cannot measure, as well as see, at this Observatory, it will be a legitimate and important if not an unanswerable argument in favor of the value and superiority of reflectors and small apertures generally. Until something of this kind is done, the fact that some one with a 4½-inch instrument claims to see a belt on one of the satellites of *Mars*, or a pale lilac streak on *Neptune*, will not be likely to discourage those of us who have only large CLARK refractors to work with, any more than the alleged discovery and repeated verification of a select assortment of companions to *Polaris, Vega, Sirius*, etc., have done heretofore.

It seems, from the recent articles alluded to, that it is a common practice with those who use reflectors to cut down the aperture under certain atmospheric conditions, for the purpose of improving the performance of the instruments in definition or otherwise. What more convincing proof could be offered of the inferior character of the instruments? Assuming that an object-glass is of the best quality, it would be preposterous to expect to do with part of it what the whole failed to accomplish. I have never had an opportunity of using a telescope where anything could be gained, under any circumstances, by working with less than the full aperture, although the experiment has been tried repeatedly. I can readily see how the definition of an imperfect object-glass would be improved by stopping out the exterior portion, and this may be true of all reflectors on poor or average nights; but it certainly is not true of any object-glass of the best workmanship. Perhaps I should mention in this connection that in all I have said here on the subject of refractors, I refer to the telescopes made by ALVAN CLARK & SONS. I do not intend to disparage the work of other makers, or to make unfavorable comparisons, but my experience has been acquired by the use of a half a dozen or more of Clark telescopes; and I think I know, from the class of observ-

ations attempted, what can be done with them. That there are refracting telescopes much inferior to them, no one will deny. That there are at this time any instruments superior to them will, I think, be maintained by few. Every one knows there are nights so unsteady that practically nothing can be done; and, unfortunately, there are many of them. Then, of course, the larger aperture is of but little advantage; but under no conditions will the reduced aperture reveal what the full aperture fails to show. The larger aperture, other things being equal, is as much superior to the smaller for observing planetary markings as for difficult double-star work, and for precisely the same reason. Prof. YOUNG has fully explained (*Observatory* for June) why the character of details, as shown by a small instrument, is frequently modified or changed under the superior separating power of the larger. If Mr. DENNING had ever used the Princeton 23-inch, or a similar telescope, he probably would not have been "surprised at the advantage which he, [YOUNG] claims for the larger instrument on all occasions;' and he would not regard this experience of an "exceptional character," even if the Princeton observers should fail to see, as I have no doubt they will, some of the planetary details that have been the subject of so much remark in the last few years. We have several large refractors in this country, and the opinions of the observers at the Naval, Princeton, McCormick, Dearborn, Warner and Washburn Observatories on the subject of the value of contracting the apertures of these several CLARK refractors can be easily obtained, and also the practice of STRUVE with the 30-inch at Pulkowa.

In view of the criticisms alluded to in regard to the performance of telescopes, it is perhaps not surprising that the author should so obviously misunderstand Prof. HALL's letter (*Observatory* for May) concerning the Washington telescope. Prof. HALL says he has seen no remarkable change on the surface of *Saturn* in the past eleven years, (and, so far as his published observations go, he has never recorded any remarkable changes on

any of the planets;) he has never seen the notch in the shadow of the ball on the ring, although he says that is "now always given in every good book on popular astronomy, and has been seen by several observers"; and even the "square-shouldered" appearance of that planet which visitors frequently ask for there, as they do here, is always missing, as well as the new stars in the Trapezium of Orion, which have been discovered several times in England and elsewhere. In this connection he candidly admits that his "work will confirm Mr. DENNING's criticism that the large telescope does not show enough detail."

From all this, Mr. DENNING comes to the conclusion that Prof. HALL gives a "thoroughly discouraging report" of the 26-inch refractor! And because the Washington observer found that "usually a power of 175 gave the best result" on *Mars,* the inference is drawn that the definition of the great telescope is imperfect! If there is a practical observer who would not give that as his own experience in any class of work, however high powers he may use at times and places, I have no idea where to find him. Visitors usually wish to see objects with the highest powers, but the working astronomer finds under ordinary atmospheric conditions that the lowest power which will show a given object is the best for real work. I have repeatedly used, with advantage, a power of 1400 on a CLARK refractor of only 12 inches, but a power of 200 or 300 "usually" gave the best result, and I have no doubt this would be true of any good instrument. It is hardly necessary to say that when a high power can be profitably used on a 0″.2 pair, there is nothing in the way of observing any planet with it. Such nights, however, are too rare in most latitudes to represent the ordinary working powers.

I have no wish to attempt to furnish a commentary on Prof. HALL's communication, for no one writes more plainly and directly on all astronomical subjects. His published work has been singularly free from all padding and fine writing, and he has no wild speculations, or marvellous celestial observations to

ventilate. I have had no communication with Prof. HALL on this subject, and do not speak with any authority; but I would suggest the propriety of ascertaining, directly from him, if there is any further doubt as to this question, whether he really took a discouraging, melancholy view of his failure to see so many of the wonders revealed by small telescopes, or whether it was not a delicate form of intimating a wholesale want of faith in the existence of the aforesaid marvels.

CHICAGO, July 15, 1885.

COMMENSURABILITY OF MOTIONS.

BY ASAPH HALL.

It is well known to astronomers that if two planets or satellites, in motion round the same center of attractive force, have their periodic times, or mean motions, nearly commensurable, there will exist in the motions of these bodies certain curious and interesting peculiarities. About two centuries ago it was observed that the motion of *Jupiter* was slowly accelerated, and that of *Saturn* retarded. These irregularities perplexed astronomers for a long time, but at last they were explained by LAPLACE. He pointed out the fact that since twice the period of *Saturn* is nearly equal to five times the period of *Jupiter*, the mutual attraction of these planets produces a large irregularity in their motions; and this irregularity itself has a period of about nine hundred years. Many other similar cases have been found in our solar system, though none where the irregularity is so large. The masses of *Jupiter* and *Saturn* are so great that the mutual perturbations are very large, and the problem of computing them is a difficult one. LAPLACE gave the first investigation, and was followed by PONTECOULANT and others, and especially by HANSEN in his elaborate prize memoir on this subject. Recently, LEVERRIER has investigated this question, but unfortunately his tables of *Saturn* are not much better than the old ones of BOUVARD published in 1821.

But suppose the motions of two bodies should be exactly commensurable, what may we expect under such conditions, and would such a system be stable? This question is not directly answered in the *Mecanique Celeste*, although it is safe, I think to infer the opinion of LAPLACE that there is nothing unstable in such a system.

Still the belief that such a system would be unstable, and would be destroyed by the slightest disturbance, seems to prevail extensively, and even among some astronomers of repute. Thus gaps in the ring of asteroids, and divisions in the ring of *Saturn* have been explained on the theory that it is impossible for bodies to move in such places, since their motions would be commensurable with those of certain planets or satellites. But such conclusions do not rest on any solid foundation, and seem to be drawn from the formulæ and expansions of the *Mecanique Celeste* and their application to an extreme case. All such formulæ, however, are derived under certain assumptions, and we must be cautious how we undertake to limit the phenomena of the universe by our interpretation of them. HANSEN has remarked that in the case of commensurable motions, the common formulæ must be modified to meet the new conditions. An interesting discussion of the case will be found in *Hendrick's Analyst* for April, 1874. This is by Mr. G. W. HILL, and he shows that commensurability of motions has no marked connection with the stability of a system. But since the invention of the telescope we have had an example before our eyes which should have prevented too hasty conclusions in this matter. It is that of the three inner satellites of *Jupiter*. So far as observations show, the motions of these satellites are exactly commensurable, and yet this system shows no sign of instability or decay. The consideration of such a system should have warned us against too general deductions from our formulæ.

It is worth while to notice, in this connection, a curious case brought forward by LAPLACE and which for a time caused much discussion. It had been the custom to teach that the *Moon*

was made to give light to the *Earth*. But LAPLACE found a special case of the motion of these bodies which he announced as an improvement in the present arrangement. He says: "If, at the origin, the *Earth* and the *Moon* had been placed on the same right line, at distances from the *Sun* proportional to one and one plus one one-hundredth; if moreover, they had been given velocities parallel and proportional to these distances, the *Moon* would have been continually in opposition to the *Sun*; these two stars would have succeeded each other above the horizon, and as, at that distance, the *Moon* could not be eclipsed, its light during the night would have replaced the light of the *Sun*." This bold improvement of creation, by means of which we should always have a full moon, was startling, and brought out criticism. In a Latin essay, published at Rome in 1825, a writer took the ground that on account of refraction and parallax the conditions proposed by LAPLACE would never exactly occur. But such criticisms are trivial and they produced no effect. It was reserved for the mathematican, LIOUVILLE, to show in 1842 that the system proposed by LAPLACE is essentially unstable, and could never exist in Nature. This point seems to have been overlooked by LAPLACE, since he repeats his assertion in the *Systeme du Monde*.

THE ENDOWMENT OF LITCHFIELD OBSERVATORY.

By the kindness of some unknown friend a copy of the Utica *Morning Herald* is in hand containing a sketch of the late EDWIN C. LITCHFIELD, who endowed the Litchfield Observatory, of Hamilton College, Clinton, N. Y.

Mr. LITCHFIELD graduated from Hamilton College in the class of 1832, studied law at Hudson, was admitted to the bar and took up a residence in Brooklyn. By means of fortunate investments in real estate and railroad stocks, he soon became wealthy, at the same time fostering a lively interest in the progress of the arts and sciences.

It is said of him that he was generous with his wealth, public spirited and an ardent lover of pictures and statuary, having of the latter one of the finest collections in this country. His interest in astronomy was shown by his endowment of the professorship of astronomy in Hamilton College. On this account the trustees of the College appropriately gave his name to the Observatory, by which it has been known since the year 1866. The amount of the endowment is $30,000, the income of which is devoted to the payment of the Director's salary and the contingent expenses connected with the Observatory.

Dr. C. H. F. PETERS, who was director of the Observatory at the time of its endowment, was elected the first "Litchfield professor of astronomy" and continues in that position at the present time. When liberal men make large gifts, as in this instance, it is not a common thing that they be on the watch for opportunities to make smaller gifts of money for useful things, and besides, to tender such aid unsolicited. A single instance will illustrate. In 1869 Dr. PETERS desired to fit out an expedition to observe the total eclipse of the *Sun* in August of that year, and he applied to the College for aid, but without success. Mr. LITCHFIELD accidentally hearing of his failure, at once authorized him to organize such an expedition as he knew to be necessary for observing the eclipse. Knowing that a small portable telescope was needed, Mr. LITCHFIELD gave an urgent order for such an instrument, the best of its kind, that STEINHEIL SONS, of Munich, could make, requiring delivery in time for the expedition. It is almost useless to add that the telescope was a complete one, if it be stated that its accessories contained a five-prism direct-vision spectroscope, when the use of such an instrument had scarcely been known, by anybody, a half decade of years. Subsequently, Mr. LITCHFIELD had this small telescope mounted at the Observatory, at his own expense; authorized the printing of five large volumes of the astronomical work which the Observatory had done, and was doing, and furnished a competent assistant, so that work could be reduced and prefaced for the printer while observation was going on.

The work now ready to publish runs through twelve years of observations of solar spots, of planets and comets, and variable stars, etc. The zone star observations, of which over 100,000 have been made, are not included in the plan.

It is generally known to astronomers that the twenty charts already published at Dr. PETERS' own expense cover parts of this work so far completed. In the free distribution of these charts the observatories and leading scientific societies of the world hove become gratified recipients of his personal generosity. In January, 1869, at the alumni meeting of Hamilton College, Dr. PETERS spoke of Litchfield Observatory at length, closing with the following paragraph:

"Not without struggle, however, has been the life of our Observatory. Three years ago it seemed as if it were doomed to lose its character as a scientific institution, to become assimilated to the fashions of observatories in other colleges, and it would have died, had not an alumnus of Hamilton College come forward and saved it. Need I tell you his name? Where is an alumnus who is ignorant of what EDWIN C. LITCHFIELD has done? Nor does it become me to praise him here; to me only the duty belongs, and a pleasant duty it is, to double my efforts, and show to the world by deeds and facts, that his liberal endowment has not been in vain, but bears useful fruit. Let the Oriskany raise its waters above its bed; let the Hill, that beautiful Hill, where we all have tasted the fountain of literature and of knowledge, let the Hill itself, by some geological catastrophe, be swept away, with eveything terrestial upon it—in the heavens written will remain testimonials that will tell the tale of the Litchfield Observatory of Hamilton College."

When the news of the death of Mr. LITCHFIELD, which took place in France, Monday, July 20, reached Hamilton College, Dr. PETERS fittingly signified the sad fact at Litchfield Observatory, in knell and drapery and flag at half-mast.

Of his departed friend "he spoke in terms of deep feeling and kindly eulogy." He said:

"Mr. LITCHFIELD'S liberality was as free as it was generous. He was happy in helping to advance the interests of science. His solicitude for this Observatory at no time flagged, and he was proud of the association of his name with it."

A worthy tribute to a worthy man, from one of America's oldest and ablest astronomers.—*Editor.*

ECLIPSES FOR YOUNG STUDENTS.

H. A. HOWE.*

It is customary in many colleges to have the advanced students in astronomy compute an eclipse of the *Sun*. Since few students have any genuine liking for computation, this exercise is regarded by the large majority of them as the climax of their astronomical tribulations.

The object of this article is to show how a class in a high school, or the preparatory department of a college, can be and has been interested in predicting an eclipse. This was accomplished by reducing the mathematical work to be done by the pupil to a small amount of mere arithmetic, trigonometry being excluded. If an eclipse comes during the portion of the school-year allotted to astronomy, the teacher will have little difficulty in interesting his scholars in the prediction of its phases, and they will watch eagerly for the verification of their expectations, on the day of the eclipse.

In March of this year a class ignorant in the main of both geometry and trigonometry computed the solar eclipse of March 16, 1885, in the following manner:

On page 414 of the American Ephemeris, they found the elements of the eclipse given for 3, 4, 5, 6, 7 and 8 hours of Greenwich mean time. From page 45 they took the tabulated values of the *Moon's* right ascension and declination for each of these hours. From page 39 by means of the hourly variations they easily computed the right ascension and declination of the *Sun* for each of the same hours. The teacher had previously computed the parallaxes (in right ascension and declination) for both bodies as seen from Denver, for these hours, and gave the corrections to the class, explaining that the Almanac gave the apparent places as seen from the *Earth's* center, and that by applying the reductions for parallax they obtained the positions of the two bodies as they appeared from Denver. The co-ordinates being thus corrected, the corrected right ascension and declination of the *Moon* at each hour were subtracted from the corresponding values for the *Sun*, and the

*University of Denver, Colorado.

results tabulated. The scholars were provided with paper ruled in squares, which in the present instance were one-fifth of an inch on a side; letting one-fifth of an inch represent 100 seconds of arc, a circle was drawn in the center of the sheet to represent the *Sun*, its semi-diameter (964″) being given in the Almanac on page 414. The differences of right ascension and declination above mentioned were reduced to seconds of arc, the former being multiplied by 15 and also by the cosine of the mean of the declinations of the two bodies, the teacher furnishing the cosines. By means of these differences the position of the *Moon's* centre with reference to that of the *Sun* (which was considered stationary) was located on the paper for each hour, one-fifth of an inch still representing 100″. The *Moon's* center was placed at the right of the *Sun's*, when the *Moon* was east of the *Sun*, and above when it was north. Each position of the *Moon's* center was then connected with the nearest one by a single line, these lines forming a broken one, which was almost straight. The semi-diameter of the *Moon* being found in the Ephemeris, circles were drawn to represent the *Moon* at the different hours. Two other circles were drawn representing it at first and at last contact, their centres being on the broken line. Thus a representation was made of the path of the *Moon* across the *Sun's* disc. It then remained to find the times of contact. The diagram made it evident that the time of first external contact was a few minutes after $4h$. A measurement of the plot showed that the *Moon's* center at the time of first contact was at a point whose distance from the position of its centre at $4h$ was about 0.18 of the distance between the positions of the center at $4h$ and $5h$. Hence the time of first contact was $4h\ 18m$ or $4h\ 11m$, assuming that the *Moon* apparently gained on the *Sun* at a uniform rate. In a similar manner it was found that the time of last contact was $7h\ 4m$. Denver being just $7h$ west of Greenwich, these times reduced became $9h\ 11m$, A. M. and $12h\ 4m$, P. M., respectively. Each of these is a minute and a half in error, according to an accurate computation from the special eclipse-data of the Ephemeris.

The method above sketched may be applied to an eclipse of the *Moon*, the *Earth's* shadow being placed in the middle of the

plotting sheet. The radius of the shadow equals the sum of the horizontal parallaxes of the *Sun* and *Moon*, minus the *Sun's* semi-diameter. Instead of the co-ordinates of the *Sun*, those of the center of *Earth's* shadow, which are 12^h greater, are to be used. No parallax corrections are needed, and the computation is therefore very simple.

The occultations of stars by the *Moon* may be similarly treated, the *Moon's* place being corrected for parallax, as above.

Since the *Sun* and *Moon* are both spherical, eclipses of the former and occultations of stars by the latter readily lend themselves to simple though rigorous trigonometric treatment along the lines already pointed out. Remembering that in the case of a solar eclipse, at the times of external and internal contact, the distances between the centers of the *Sun* and *Moon* are equal to the sum or to the difference of their semi-diameters, the times of the phases can be found by the inverse of interpolation. In this process a quadratic equation presents itself for solution. But an elaboration of the method just hinted at would take us beyond the scope of this article.

Some Account of a Set of Tables, Prepared by Professor GEORGE W. COAKLEY, *for Computing Eclipses and Occultations.*

These tables are based upon the following formulæ, most of which are readily demonstrated by the principles of spherical trigonometry:

If the *Moon's* center be not far from a fixed star, or from the *Sun's* center and $\triangle$ = the apparent distance of those centers as seen from any place on the *Earth*, whose longitude west of Greenwich is λ, and its geocentric latitude φ', then the following exact formula may be demonstrated:

$$\sin^2 \triangle \cdot (1-2 \sin P_1 \cos z_1+\sin^2 P_1)=(x-\xi)^2+(y-\eta)^2 \quad (1).$$

in which

$$\left.\begin{aligned} x &= \sin (a_1-a_2) \cos \delta_1 \\ y &= \sin (\delta_1-\delta_2)+2 \sin \delta_1 \cos \delta_2 \sin^2 \frac{1}{2}(a_1-a_2) \\ \xi &= \sin P_1 \cos \varphi_1 (\mu-a_2) \\ \eta &= \sin P_1 \sin (\varphi^1+\delta_2) \sin^2 \frac{1}{2}(\mu-a_2) \\ &\quad + \sin P_1 \sin (\varphi^1-\delta_2) \cos^2 \frac{1}{2}(\mu-a_2) \end{aligned}\right\} \quad (2)$$

a_1 and δ_1 are the geocentric right ascension and declination of the *Moon*, a_2 and δ_2 of the *Sun* or star, z_1 and z_2 their geocentric zenith-distances. $P_1=\rho\ (\pi_1-\pi_2)$, or the *Moon's* local relative horizontal parallax, and μ is the sidereal time at the place (φ', λ), corresponding to the Greenwich mean time, T, at which the data are taken from the Nautical Almanac.

If the members of equations (1) and (2) be divided, the first by $\sin^2 P_1$, the others each by $\sin P_1$, they will then correspond exactly to the fundamental equations of eclipses and occultations given by Professor CHAUVENET in his Spherical and Practical Astronomy. These are also the equations employed in the American Nautical Almanac for computing eclipses and occultations. But for the purpose of constructing my tables, I have found it more convenient to divide the members of (1) by $\sin^2 1'$, and those of the other equations by $\sin 1'$, and thus express all the quantities to be used in the computation as *minutes of arc*. The equations then become, in minutes of arc,

$$\triangle^2\cdot(1-2\sin P_1\cos z_1+\sin^2 P_1)=(x-\xi)^2+(y-\eta)^2 \qquad (3).$$

$$\left.\begin{aligned} x&=(a_1-a_2)\cos\delta \\ y&=\delta_1-\delta_2+(a_1-a_2)^2\cdot\sin 2\delta_2\cdot\frac{\sin 1'}{4} \\ \xi&=P_1\cos\varphi'\sin(\mu-a_2) \\ \eta&=P_1\cdot\sin(\varphi'+\delta_2)\sin^2\frac{1}{2}(\mu-a_2) \\ &\quad +P_1\cdot\sin(\varphi'-\delta_2)\cos^2\frac{1}{2}(\mu-a_2) \end{aligned}\right\} (4).$$

In the second small term of y, δ_2 has been substituted for δ_1, as they are nearly equal, and as this term is multiplied by the small factor $\frac{\sin 1'}{4}$. CHAUVENET represents this term by E, and I shall do the same, making

$$E=(a_1-a_2)^2\cdot\sin 2\delta_2\cdot\frac{\sin 1'}{4} \qquad (5)$$

and $y=\delta_1-\delta_2+E$, E being positive or negative according to the algebraic sign of δ_2.

If now we let x' = the hourly variation or increment of x, y' that of y, ξ' that of ξ, η' that of η, and make one hour the unit of time, we shall readily obtain the following expressions:

$$\left.\begin{aligned} x' &= \cos\delta_1 \cdot \frac{d(a_1-a_2)}{dt}, \text{rejecting terms that are too small;} \\ y' &= \frac{d(\delta_1-\delta_2)}{dt} \\ \xi' &= P_1 \cos\varphi' \cos(\mu-a_2) \cdot \frac{d(\mu-a_2)}{dt} \\ \eta' &= \frac{1}{2} P_1 \sin(\varphi'+\delta_2) \sin(\mu-a_2) \cdot \frac{d(\mu-a_2)}{dt} \\ &\quad - \frac{1}{2} P_1 \sin(\varphi'-\delta_2) \sin(\mu-a_2) \cdot \frac{d(\mu-a_2)}{dt} \end{aligned}\right\} \quad (6)$$

$\frac{d(a_1-a_2)}{dt} = \frac{da_1}{dt} - \frac{da_2}{dt}$, is the difference of the hourly increments of right ascensions of the moon and sun, derived directly from the Nautical Almanac; and $\frac{d(\delta_1-\delta_2)}{dt} = \frac{d\delta_1}{dt} - \frac{d\delta_2}{dt}$, is the difference of the hourly increments of declination. For a star, $\frac{da_2}{dt}=0$, and $\frac{d\delta_2}{dt}=0$. For a star we may write logrithmically, $\frac{d(\mu-a_2)}{dt} =$ [9.419156]. The method of reducing to the case of an eclipse will be given subsequently.

It will be convenient to write $\eta = v_1 + v_2$, and $\eta' = v_1' - v_2'$ where

$$\left.\begin{aligned} v_1 &= P_1 \sin(\varphi'+\delta_2) \cdot \sin^2 \frac{1}{2}(\mu-a_2) \\ v_2 &= P_1 \sin(\varphi'-\delta_2) \cdot \cos^2 \frac{1}{2}(\mu-a_2) \end{aligned}\right\} \quad (7)$$

$$\left.\begin{aligned} v_1' &= P_1 \cdot \sin(\varphi'+\delta_2) \cdot \sin(\mu-a_2) \cdot [9.118126] \\ v_2' &= P_1 \cdot \sin(\varphi'-\delta_2) \cdot \sin(\mu-a_2) \cdot [9.118126] \end{aligned}\right\} \quad (8)$$

If all these values have been computed, or taken from the the Tables, for the Greenwich mean time, T, it is not probable that the values of x, y, ξ, η, will satisfy equation (3). But if a small correction, t, be added to T, the values $x+t \cdot x'$, $y+t \cdot y'$, $\xi+t \cdot \xi'$, $\eta+t \cdot \eta'$, ought to satisfy the equation (3) at the time, $T+t$.

At the moments of external contact, moreover, we ought to to have $\triangle = s_1' + s_2$, when s_1' = the *Moon's* augmented semi-diameter, and s_2 = the *Sun's* semi-diameter. Hence (3) will become $(s_1'+s_2) \cdot \sqrt{(1-2 \sin P_1 \cos z_1 + \sin^2 P_1)} =$

$$\sqrt{([x-\xi+t \cdot (x'-\xi')]^2 + [y-\eta+t \cdot (y'-\eta')]^2)}.$$

But $s_1' \cdot \sqrt{(1-2 \sin P_1 \cos z_1+\sin^2 P_1)}=s_1$, and we may write $\sqrt{(1-2 \sin P_1 \cos z_1+\sin^2 P_1)}=1-\sin P_1 \cos z_2$, replacing z_1 by z_2 in the small term of the first order, and rejecting the other small terms.

Hence $(s_1'+s_2) \cdot \sqrt{(1-2 \sin P_1 \cos z_1+\sin P_1)}=$
$s_1+s_2-s_2 \sin P_1 \cos z_2$.

Let $s_2'=s_2-s_2 \sin P_1 \cos z_2$, where $\cos z_2=$
$\sin \varphi' \sin \delta_2+\cos \varphi' \cos \delta_2 \cos (\mu-a_2)$.

Then s_2' may be called the *Sun's reduced* semi-diameter. In the case of occultations, $s_2=0$, hence $s_2'=0$, and we have strictly $\triangle^2=s_1^2=[x-\xi+t \cdot (x'-\xi')]^2+[y-\eta+t \cdot (y'-\eta')]^2$

As usual, we put
$$x-\xi=m \sin M$$
$$y-\eta=m \cos M$$
$$x'-\xi'=n \sin N$$
$$y'-\eta'=n \cos N$$

$$\therefore t_1=-m \cdot \frac{1}{n} \cos (M-N) \cdot \sin \psi=\frac{1}{\triangle} \cdot m \sin (M-N)$$
$$t_2=\frac{1}{n} \cdot \triangle \cos \psi$$

$T+t_1$=Gr. M. Time of nearest approach.
$T+t_1-t_2$=Gr. M. T. of 1st contact.
$T+t_1+t_2=$ " " " " last contact.

Of the eight constants, x, y, x', y', ξ, ξ', η, η', the first four are the simplest, most readily computed, and are the chief ones given in the American Nautical Almanac. The computations of the last four are by far the most laborious. But all of them are given with very little trouble in the set of seven tables now considered.

The constants depending upon the parallax, P_1, cannot be tabulated readily for all values of P_1. Hence they are tabulated for a *mean parallax* of 57′. If we denote the value of for this parallax by writing it in parenthesis, we shall have $(\xi)=57' \cdot \cos \varphi' \sin (\mu-a_2)$ and $\xi=P_1 \cdot \cos \varphi \sin (\mu-a_2)$. Hence $\frac{\xi}{(\xi)}=\frac{P_1}{57'}$; or $\frac{\xi-(\xi)}{(\xi)}=\frac{P_1-57'}{57'}=f$, f being a small factor, easily tabulated. Hence $\xi=(\xi)+f \cdot (\xi)$. Thus the value of ξ is readily derived by simple contracted multiplication from the tabulated value (ξ), for 57′. In like manner $\eta=(\eta)+f' \cdot (\eta)$,

and ξ' and η' are derived in the same manner, by the same factor, f, which is tabulated in Table I, for every unit of the third decimal place.

Table II contains the values of E, for every two degrees of δ_2 to 30°, and for every *minute* of *time* of $a_1 - a_2$ up to $6m$. But the value of E may usually be neglected.

Table III gives the values of x, and of x', for every degree of δ_1 to 30°, and for every *second of time* of $a_1 - a_2$, from $1s$ to $10s$, and then for $20s$, $30s$, $40s$, $50s$, $1m$, $2m$, $3m$, etc., up to $9m$. It will thus serve for solar and lunar eclipses as well as for occultations.

Table IV gives the values of (ξ), for every degree of φ', up to 90°, and for every $10m$ of $\mu - a_2$ up to $6h$, and thence in reverse order to $12h$. These are all given in minutes of arc, and two decimal places below the unit.

Table V gives (η), by giving (υ_1) and (υ_2), for every degree of $\varphi' + \delta_2$ and $\varphi' - \delta_2$ up to 90° and for every $20m$ of $\mu - a_2$ up to $12h$. Hence $(\eta) = (\upsilon_1) + (\upsilon_2)$, and thence $\eta = (\eta) + f'' (\eta)$. These values are also given to hundredths of minutes of arc.

Table VI gives the values of (ξ') *for occultations*, for every degree of φ', to 90°, and for every $10m$ of $\mu - a_2$ to $6h$, after which they simply change their algebraic sign, and answer for $12h - (\mu - a_2)$.

If $\frac{3}{1000}$ of these values be subtracted from them, the remainders will serve for solar eclipses.

Table VII gives the values of $(\eta') = (\upsilon_1') - (\upsilon_2')$, by giving those of (υ_1') and (υ_2') for all values of $\varphi' + \delta_2$, and $\varphi' - \delta_2$, for each degree up to 90°, and for all values of $\mu - a_2$ up to $6h$, by intervals of $10m$. The same reduction is made from occultations to eclipses, by diminishing the values by $\frac{3}{1000}$ of the same.

The tables are so arranged that the data, for determining x, x', y, y', ξ, ξ', η, η', may be taken from the Nautical Almanac with the least possible change. For example, the right ascensions of the *Moon* and *Sun*, or star, and the sidereal time need

not be changed from hours, minutes and seconds of time, to degrees, minutes and seconds of arc. The differences, $a_1 - a_2$, $\mu - a_2$ in hours, minutes and seconds of time, are used directly as the arguments for finding the constants x, y, etc., in minutes of arc. The difference of declination, etc., may be expressed as minutes of arc, and the seconds of arc may readily be written at sight from the Ephemeris as tenths and hundredths of minutes of arc. Thus the data from the Ephemeris are obtained with the least possible loss of time. A little familiarity with the tables and with the mode of computing will lead to a very rapid use of them, saving a great deal, both of time and labor, especially in their application to the computation of occultations. They serve also for computing lunar eclipses, occultations of planets, and transits of *Mercury* and *Venus* over the *Sun*, with sufficient accuracy for observing these phenomena.

UNIVERSITY of THE CITY of NEW YORK.

REPORTS OF EUROPEAN OBSERVATORIES.

From the V. J. S. *der Astron. Gesell.* the following account of the work at various European Observatories for the year 1884 is condensed.

Berlin:—The large meridian circle has been dismounted and has received important mechanical improvements.

The observations on the southern half of the Berlin Zone were temporarily stopped during the year. Dr. KUESTNER has begun a series of observations with the object of determining the Constant of Aberration by measures of the difference of zenith distances of pairs of stars in the same R. A. and equal and opposite Z. D. The work is to be finished in 1885.

Dr. KNORRE has made a large number of observations with the 9.6 equatorial for the positions of asteroids, comets and faint stars. The planet *Hypatia* was found by him July 1, 1884.

Dr. BATTERMANN is regularly observing occultations, both immersions and emersions.

Dr. MARCUSE has charge of the heliometer and has made thirty-three determinations of the solar diameter, etc.

Vol. V of the Berlin observations has been published during the year.

Berlin:—German Transit of Venus Commission. Report of Dr. AUWERS on the work of the computing bureau. This report of Dr. AUWERS relates first, to the *observations*. These are of three kinds: 1st. Observations before the expeditions for practice and for the investigation of special points; 2nd. Observations at the stations, and 3rd. Observations made after the return of the parties.

A list of the heliometer measures of each observer comprised in these classes is given separately and a summary, from which it appears that the total number of complete measures with the four heliometers was,

Before and after the expeditions	1769
At the stations themselves	1074
In all for thirteen observers	2843

Four of the observers made more than 320 apiece. The reductions are fully described in the report of eighteen octavo pages, to which reference must be made. It is already a summary and can not be abridged with advantage. A reference to it will show, in a very instructive way, how thorough is the cooperation of observatories and astronomers in Germany and outside of it.

Bonn:—2881 zone stars (400 fundamental stars) were determined in the A. G. Zone. The southern *Durchmusterung* has required the examination of some 750 places in the sky to solve doubts. In December 1883 the charting of the stars on the maps was again begun and finally completed in March 1885. The catalogue will contain 133,658 stars between —2° and —23°, 692 more are given north of these limits and 479 south.

Brussels:—The transit and mural are used to observe moon culminating stars. A general catalogue of the stars observed at Brussels in the years 1857—1878, reduced to 1865, will be printed during 1885.

Dresden:—(Private observatory of Baron ENGELHARDT.) 242 observations of the positions of comets, planets and nebulæ (198) have been made with the 12-inch equatorial, besides minor observations.

Dusseldorff:—Professor LUTHER discovered planet 241, *Germania*, during the year on his Berlin chart for 0 hours. Since 1847 150 planets have been observed 1233 times at Dusseldorf with the 6-inch telescope.

Frankfort-on-the-Main:—(Private observatory of Herr EPPSTEIN.) The star guages were continued on sixty-two nights, in 682 places, 2714 fields containing 25,875 stars.

Sun-spots are also regularly observed here.

Geneva:—The large equatorial has been provided with a spectroscope. Besides the regular observations relating to meteorology and to chronometers, observations of comets and of the satellites of *Saturn* have been made.

Gotha:—The computations of the Zone 20°—25° of the A. G. have been prosecuted, The meridian circle is used to observe moon culminating stars and others of MAYER's Catalogue; the equatorial for planet and comet observations.

Grignon:—has made various observations on solar-spots, comets, meteors, lunar eclipses, spots on *Venus* and *Mars*, etc., for which observations and the conclusions drawn from them, reference must be made to the original report.

Helsingfors:—Dr. ANDERS DONNER was appointed director to succeed Professor KRUEGER, in 1883. The meridian instrument has been used to re-observe some 500 stars of the Helsingfors Zone +55° to +65°, *Victoria* and *Sappho*, the *Moon* and moon-culminating stars, etc.

Hereny:—Vol. II will be published in 1885. Spectrum observations of β *Lyræ* have confirmed the variability of the spectrum of this star. Many other spectroscopic observations of stars, planets and comets have been made.

Karlsruhe:—The principal work of the observatory is the determination of the positions of southern stars to 8 magnitude, inclusive. In the Zone 0° to —4°, 5000 observations have

made and the Zone —4° to —7° has been commenced. The single positions have probable errors of ±0s.028 and ±0″.39. The 6-inch refractor has been remounted.

Kiel:—The equatorial has been used among other things to observe Σ 2164 for parallax by Dr. LAMP. New comets were regularly observed.

The meridian circle is used to determine the positions of stars between 79° and 82° north.

The Zone catalogue (55° to 65°) is in preparation.

Leipzig:—A six-inch heliometer by REPSOLD is in process of construction and will be delivered at the end of 1886. A universal instrument has been ordered with which a long series for latitude will be commenced. 10,541 observations (123 zones) of Zone stars have been made in the new Zone (+5° to +10°) and the reductions for the old Zone (+10° to +15°) are in progress.

Leipzig:—(Private observatory of Dr. ENGELMANN.) 2600 observations of 430 double-stars have been made, mostly of STRUVE's doubles. An investigation of the constant errors is in progress. It appears that the *difference* in magnitude of the components influenced the *constant* errors in a marked degree. OTTO STRUVE's list of double-stars for comparison have been observed; about 500 measures have been obtained.

Lund:—Dr. DUNER continues his observations of the spectra of stars, measures of double-stars and positions of comets. No account is given of the Lund Zone, nor of Dr. DUNER's spectroscopic *Durchmusterung.*

Milan:—The 8-inch refractor has been used to measure 255 double-stars, and for observations of comets. The measures of the ellipticity of *Uranus* "can not yet be considered to be free from all objections."

The observations on *Mars* seem to confirm previous results as to the duplication of canals, etc.

The large dome for the 18-inch refractor is nearly completed and the instrument may be mounted towards the end of 1885.

Munich:—The 10-inch equatorial is now remounted and the REPSOLD micrometer has been studied. It will be principally

used to determine the parallaxes of Ll. 28298, 26 *Draconis*, Gr. 2875, Br. 3077.

The Munich zones contain 34,000 stars, of which 9,800 require re-observation. This will be accomplished in zones 6° broad.

The old Munich zones are re-computed and a catalogue (for 1880) is in preparation.

O'Gyalla:—1610 observations for the spectroscopic *Durchmusterung* of the southern sky have been made. Color observations with the Zœllner photometer are also continued as well as various other photometric and spectroscopic series.

Potsdam:—Researches are in progress on a new determination of the wave lengths of a large number (300) of the Fraunhofer lines; on the influence of temperature on the refraction and dispersion indices of fixed substances; on the reflective power of various substances; on the absorption-spectra of such substances as are used in photography, etc.

Jupiter and *Mars* were regularly observed and the nebulæ observations are concluded.

The photometric measures embraced long series of determinations of the brightness of the major planets and of seven of the asteroids. Many variable and red stars were also measured. Determinations of the brightness of stars by photography have also been made, and a number of photographs of clusters have been taken.

Prague:—(Private observatory of Professor SAFARIK.) 1482 observatians of ninety-two stars were made in 121 observing nights.

Taschkent:—The main object of the observatory is to co-operate in the surveys and explorations of Turkestan. Four latitudes and longitudes were determined in 1884. Comets, asteroids and solar-spots have been observed also.

Upsala:—The unpublished observations of nebulæ and clusters up to 1880 are now prepared for the press. With the Zœllner photometer it is proposed to determine the magnitudes of the comparison stars used by ARGELANDER, SCHOENFELD and OUDEMANNS for variables.

Zurich:—The sun-spots are assiduously observed here. The maximum occurred in December 1883 to January 1884.

EDITORIAL NOTES.

Though BARNARD'S comet was faint when the announcement of its discovery was made, it has been seen, and positions recorded at the larger observatories in all parts of the world.

Dr. HOLETSCHEK, of Wien, Austria, publishes for the new comet the following,

ELEMENTS.

Perihelion passage,	1885.16 Berlin M. T.
Perihelion from node	198° 43′
Longitude of node	93 30
Inclination	75 53
Perihelion distance	2.2903

These elements depend on observations of July 9, Cambridge; July 11, Arcetri, Wein, Straasburg, and July 13, Wien.

VANDERBILT UNIVERSITY OBSERVATORY.

On July 15, 10*h* 35*m* 30*s*, Nashville mean time, the position of BARNARD'S Comet was as follows:

R. A.	17*h* 7*m* 0.17*s*
Decl.	9° 24′ 10″.9

The above was the mean of twelve observations both rings of the micrometer being used, and corrections for refraction being applied.

E. E. BARNARD.

BARNARD'S COMET.

According to Prof. CHANDLER'S elements this comet had already passed its perihelion at the time of discovery and is, consequently growing fainter. This supposition accords with my observations as I am certain that it is now less bright than on July 8th when I could easily see it with my 4½-inch comet seeker. No tail was noticed even with the great telescope, but on the evening of the 11th (my next observation) a tail 2′ long was seen with the 15-inch refractor which still continues visible though now very faint. There appears to have been, besides the real nucleus, several points of light, seen, only during moments of fine definition. Some were, no doubt, imaginary like the excessively minute stars one sees, or thinks he sees, with high powers and intensely strained vision in the Ring Nebula in *Lyra*, but which instantly vanish as soon as the attention is turned to them.

The most interesting feature of this comet is its great perihelion distance, surpassing in this respect every known comet save that of 1729.

No prior claim to discovery has been filed with me, and Mr. BARNARD is therefore clearly entitled to the Warner Prize of $200. This is his fourth reception of this prize, making an aggregate of $800, received from Mr. H. H. WARNER.

LEWIS SWIFT.

A Remarkable Meteor.

A meteor of almost unexampled size and brilliancy was seen from this locality and was witnessed, in fact, from the entire state, at about 10 minutes past 9 o'clock, on the evening of July 17th. From personal observation I can give no data regarding it as I was inside the observatory and saw only its blinding flash through a north-east window, but from two intelligent persons who saw it through nearly all of its visible path, and who were able to mark it by the stars adjacent, I am able to locate its path with some approximate accuracy. Mr. Rebasz, one of my reliable informants first saw it in the center of the right angled triangle formed by the stars Alpha, Gamma and Delta *Cygni*. He thinks, it burst upon his vision so suddenly, that it must have made its first appearance near Delta. It passed between Alpha and Gamma—one quarter the distance between from Alpha—and near Xi *Cygni*, and continued on in a north-easterly direction to within about 30° of the horizon, when it burst into many fragments of three different colors and disappeared. We estimated the time of visibility at three seconds. My other informant agrees with Mr. Rebasz, and, by aid of the stars, pointed out to me its path. He shows that after leaving the cross of *Cygnus*, it passed midway between Alpha *Cassiopeiæ* and Beta *Pegasi* and exploded. These are reliable facts which set at naught the random stories of the public prints that it moved from S. E. to N. W., and, indeed, in every direction but the true one. Its motion, therefore, was direct and not retrograde.

With the last witness were three others, and all aver that they heard after the explosion a report. Each, to himself, marked the elapsing time, as follows: $2m$, $2\frac{1}{4}m$, $2\frac{3}{4}m$, and $3m$.

Popular statements concerning the size, brightness, height, direction of path, length of train, etc., of bright meteors are sometimes very amusing. They say, a certain number of rods above the *Earth*; "had a tail six feet long, and four inches in diameter," and many other things equally ludicrous.

After the very fine meteor of July 3rd, 1884, which was seen over nearly all of the northern states, and regarding which I was quite anxious to collect data for determining its size and height, in response to a published request I received about two hundred descriptive letters, but the statements given were so discordant as to render the attempt futile. However, I traced its visible path from Buzzard's Bay, Mass., to Marion, Ohio, and yet one man testified that he saw it fall into Seneca Lake, while another declared that it struck the ground about ten rods from where he stood. One correspondent kindly informed me that its size was just equal to that of a samp-bowl. A woman in Canada assured me (no doubt she thought the information all that was necessary for the computation of its orbit) that it passed exactly over her garden.

Warner Observatory, July 20, 1885. LEWIS SWIFT.

CINCINNATI OBSERVATORY.

The observation of Comet Barnard (1885) at the Cincinnati Observatory, made July 17, $9^h\ 53^m\ 32^s$, Mount Lookout mean time was as follows:

Apparent R. A.	$17^h\ 03^m\ 40.26^s$.
Log. $p \times \Delta$	8.789
Apparent Decl.	$-10°\ 29'\ 55''.8$
Log. $p \times \Delta$	0 826.

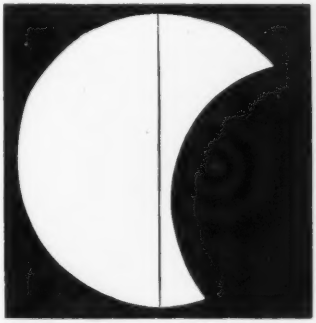
POSITIONS OF COMPARISON STARS.

R. A. 1885.0	Red. to app.	Decl. 1885.0	Red. to app.
$17^h\ .03^m\ 27.40^s$	$+2.955^s$	$-10°\ 22'\ 15''.8$	$+7''.8$

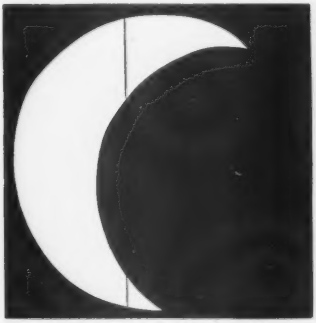
Authority, WEISSE, RADCLIFFE, *Astr. Nach.* 608, LEMONT.

J. C. PORTER,
Astronomer.

Secretary H. E. MATHEWS, of Lick Observatory, gave under date of July 22, interesting data respecting the partial eclipse of March last, He says; "The seventy-four negatives taken during the eclipse were all carefully timed, and a record kept in the same manner as photographic work was recorded during the transit of *Venus* in 1882. 'Dry plates' were



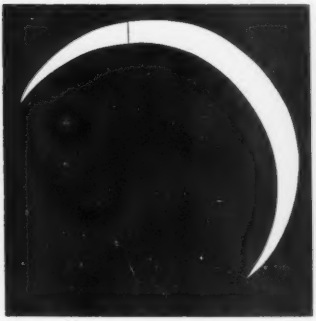
Negative No. 2, at 20 h 14 m 10 s.



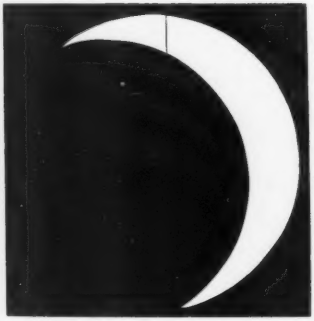
Negative No. 13, at 20 h 33 m 57 s.

used with excellent success, the faint lines of the reticule plate being plainly visible in all the seventy-four negatives, and indistinctly visible on only four. To Mr. MATHEW'S surprise the few that are less distinct are those showing the least of the surface of the *Sun's* disc, and the cause of indistinctness proved to be too much light, as the plates developed too readily. At the time of greatest obscuration the *Sun's* light acted more powerfully, as though concentrated in the narrow rim of light in view

and exactly the same features appeared at the cusps, which uniformly showed a more rapid development of the plates at these points. The opening in the slide used most of the time was one-twentieth of an inch in width, but the time of the passage of the slit before the sensitive plate is not given.

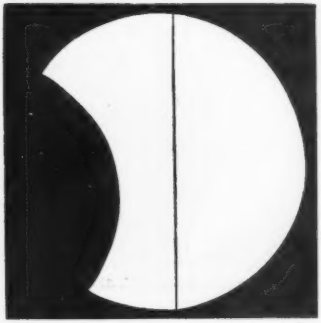


Negative No. 24, at 21 h 0 m 51 s.

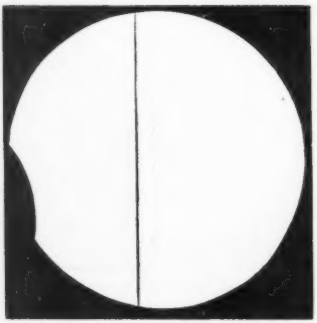


Negative No. 30, at 21 h 10 m 2 s.

One dozen of these negatives have been sent to Washington, but probably the remainder will be measured at the Lick Observatory by the aid of the new measuring apparatus just received, which belongs to the Observatory.



Negative No. 45, at 21 h 51 m 49 s



Negative No. 69, at 22 h 17 m 45 s.

The time given in connection with each photograph from which the above cuts are made, is for the astronomical date of March 15, 1885, and was the mean time at Lick Observatory, probably within one second, the transit observations for time not having been carefully reduced at the time of writing.

The last report of the Observatory in Yale College shows active work in various ways, chiefly in the horological bureau, the thermometric bureau and with the heliometer. Dr. LEONARD WALDO is in charge of the horological bureau. He has received fifty-eight time-pieces for rating, during the year; is still at work on new clocks of precession for a watch-rating standard; has a new mercury-cup relay for securing the transmission of time-signals, in which it is claimed, that the break of the electric circuit can be adjusted to any degree of nicety desired. Time observations have been made on one hundred and forty-two nights during the year, ranging from six to twenty observations in each month.

Mr. ORRAY T. SHERMAN, astronomer in charge of the bureau of thermometers has examined 5,696 instruments and reported on the same. The thermometers were chiefly for chemical and meteorological uses and physical standards. He reprints a brief, though useful, study of thermometers intended to measure temperatures from 100° to 300° C. from the July *American Journal of Science and Arts*. The case of thermometers in rapid change is also considered and some light given on the question, whether it is possible to derive from the disturbed reading the temperature of the glass, the temperature of the mercury and the effect of friction, things important to know in delicate standards.

Since October last Mr. ELY has taken magnetic observations on 17 different days for declination, horizontal force and dip. It is known that neighboring rocks disturbed the observations, but how much is not known.

In measuring the diameter of *Venus* with a GRUBB filar micrometer attached to equatorials of 8,$\frac{5}{6}$ and 4 inches aperture respectively, results were found to differ considerably. The 8-inch made the diameter greater than the 6-inch by 0″.22, and greater than the 4-inch by 0″.27. The average error of observation does not exceed 0″.05.

The principal object of research by Dr. W. L. ELKIN, astronomer, in charge of the heliometer, has been the triangulation of the *Pleiades* The present plan includes 69 stars ranging downward to 9.2 magnitude whose distances and position-angles from *Alcyone* are to be determined. The relation of the stars of BESSEL's list to the four stars that form a large quadrilateral, enclosing the major portion of the group, has been determined in a fairly complete manner. Work in this direction may be continued also.

The heliometer has been used in getting 88 independent positions of the *Moon* on 36 nights; in determining the places of three craters and the diameter of the *Moon* in 36 directions; 102 measures on the diame-

ter of *Saturn's* outer ring, besides other short series of observations on *Venus* and *Titan*.

The publication of this work will be awaited with interest.

Observations of Comet Barnard (1885). Made at the U. S. Naval Observatory with the 9.6-inch equatorial.

(Communicated by Commodore GEO. E. BELKNAP, Superintendent.)

Date	Wash. M. T.	$\Delta\alpha$	$\Delta\delta$	Comp.	App. α	log. Δp	App. δ	log. Δp	Star	Obs.
	h m s	*m s*	° ′ ″		*h m s*	*s*	° ′ ″			
July 11	9 43 44	−1 10.53	− 7 56.5	20.4	17 14 15.37	8.298*n*	−7 6 18.0	0.802	a	F
12	9 44 57	+1 13.51	+ 4 2.5	15.3	17 12 25.60	7.761*n*	−7 40 24.6	0.806	b	F
14	10 7 21	+3 28.58	− 8 54.2	20.4	17 8 49.57	8.799	−8 48 59.9	0.728	c	F
15	9 40 39	−0 16.05	−13 29.7	15.3	17 7 6.45	8.349	−9 22 7.0	0.722	d	F
16	9 15 28	+0 8.96	− 8 36.8	20.4	17 5 24.08	8.292*n*	−9 55 35.1	0.726	e	F
17	10 32 14	+0 8.88	− 8 1.5	20.4	17 3 38.42	9.166	−10 30 9.5	0.744	f	F

COMPARISON STARS.

Star	α 1885.0			δ 1885.0			Reduction		Authority.		
	h	*m*	*s*	°	′	″	*s*	″			
a	17	15	22.96	−6	58	30.5	+2.94	+9.0	Schiel		6193
b	17	11	9 14	−7	44	35.8	+2.95	+8.7	Weisse	XVII,	151
c	17	5	18.04	−8	40	13.9	+2.95	+8.1	Weisse	XVII,	39
d	17	7	19.54	−8	8	45.5	+2.96	+8.2	Schjel		6146
e	17	5	12.17	−9	47	6.0	+2.95	+7.7	Weisse	XVII,	37
f	17	3	38.42	−10	22	15.8	+2.95	+7.8	Weisse	XVII.	3

E. FRISBY.

NAVAL OBSERVATORY, WASHINGTON, July 21, 1885.

ASTRONOMICAL NOTES.

Comet Barnard. The comet has been regularly observed here since the night of discovery upon every favorable occasion. The last observation of the object being on the night of August 13th, when it appeared very faint. Since the withdrawal of the *Moon* in the last of July, the comet has generally been quite faint, though it could doubtless have been followed for a couple of weeks longer had it not been for increasing moonlight. *A fine mean time clock and a chronograph* have been ordered from the E. HOWARD Watch & Clock Co., of Boston, and from WARNER & SWAZEY, of Cleveland, Ohio, respectively. The clock has arrived and is being put into working order, and the chronograph will doubtless soon arrive. These are two things the observatory badly needed. The clock has an electric signalling device for the distribution

of time-signals, so that should it become necessary we can supply the city and surrounding towns with accurate time.

The August Meteors were much more frequent this year than last, and quite a number of fine ones were seen; other work prevented any accurate observations being made. Unfortunately, the nights of August 10 and 11th (also the 12th) were cloudy, But the 7th, 8th and 9th showed a gradual increase. On the night of the 9th before eleven o'clock many fine ones were seen traversing the southern sky from the direction of *Cassiopeiæ* and *Perseus*, each of these left trains, permanent to the eye for a second, but never remained long enough to be caught with the telescope.

The nebulæ run upon lately with the 5-inch, were G. C. 5957 (supplement) and G. C. 4599. The first is small and somewhat faint; it is *close* preceding a small 9-magnitude star, and is gradually pretty much brighter in the middle. There is an irregular figure of four or five small bright stars a short distance *s. f.* this nebula. G. C. 4573 at this observation was not seen. The second nebula (G. C. 4599) was very difficult with 5-inch. It is *close f.* three or four small bright stars. The light from these stars makes it difficult to see the nebula, which is small pretty suddenly much brighter in the middle to a flickering, ill-defined nucleus. I can not see why it should be called bright in G. C., probably in the southern hemisphere it is much brighter.

Large Nebula not in G. C. On the night of July 7th, I swept up a large nebula close to the southern horizon. Two equatorial pointings gave its place:

$$\left.\begin{array}{l}\text{A. R.} = 17^h\ 16^m\ 43^s \\ \text{Decl.} = -48^\circ\ 21'.3\end{array}\right\} 1885.0$$

Neither G. C., nor supplement, contains this large nebula. Professor SWIFT informs me it is one of DUNLOP'S. It must be quite a bright object to be seen from this latitude. It is in field with and about $\frac{1}{2}^\circ$ *n. p.* a 6 mag. or 7 mag. star.

VANDERBILT UNIVERSITY OBSERVATORY. E. E. BARNARD.

THE SEPTEMBER PLANETS.

The time used is that of the 90th meridian in astronomical reckoning.

Mercury	rises	September	5	$17^h\ 16^m$.
"	"		15	16 22.
"	"		25	16 41.

The planet is in inferior conjunction Sept. 1, 23^h; in conjunction with the *Moon*, Sept. 7th, and 37′ south; in greatest elongation W. 17° 52′ September 15th 3^h; in perihelion September 19 13^h, and in conjunction with *Jupiter* September 26, 15^h, *Mercury* being 52′ north.

Venus sets September 5 7*h* 52*m*.
" " 15 7 37.
" " 25 7 23.

It is in conjunction with the *Moon* September 10, 15*h* 36*m*; and September 12 enters the descending node.

Mars rises September 5 13*h* 13*m*.
" " 15 13 5.
" " 25 12 57.

Is in *Præsepe* September 24.

Jupiter sets September 5 6*h* 52*m*.
" " 16 6 14.
" " 26 5 39.

Is in opposition with the *Moon* September 8, 4*h* 4*m*. Conjunction with the *Sun* September 8th, 4*h* 7*m*.

Saturn rises September 5 12*h* 0*m*.
" " 15 11 24.
" " 25 10 47.

and is in quadrature with the *Sun* September 30, 18*h* 18*m*.

Uranus sets September 5 7*h* 24*m*.
" " 17 6 39.
" " 26 6 5.

and is in conjunction with the *Moon* September 9, 6*h* 34*m*, being only 4′ north of it.

Neptune rises September 5 9*h* 30*m*.
" " 17 8 42.
" " 25 8 11.

and is in conjunction with the *Sun*, September 27 14*h* 16*m*. The *Sun* is totally eclipsed September 8th, its path of totality being almost wholly in the South Pacific Ocean, between Australia and South America and ending 75° south latitude. Its path touches land only at New Zealand.

There will be a partial eclipse of the *Moon*, September 23rd, visible at Washington, also on the Atlantic Ocean, North and South America and the Pacific Ocean.

The phases for Washington mean time are:

Moon enters penumbra	September	23	11*h* 52.3*m*
" " shadow	"	23	13 6.4
Middle of eclipse	"	23	14 40.
Moon leaves shadow	"	23	16 13.7
" " penumbra	"	23	17 27.7

First contact of shadow with *Moon's* limb 37° from the north point toward the east when the *Moon* is in the zenith in longitude 95° 45′ west of Greenwich and in latitude 0° 13′ south.

Last contact of shadow with *Moon's* limb 73° from the north point towards the east when the *Moon* is in the zenith, in longitude 141° 37′ west of Greenwich, and in latitude 0° 18′ north.

Magnitude of the Eclipse=0.790 (*Moon's* diameter=1).

September 1 *Aldebaran* is occulted by the *Moon* at 8*h* 29.5*s*.

Mercury is also occulted by the *Moon*, September 7, 9*h* 19.8*s*.

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6. Twilight Belt.
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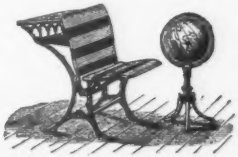

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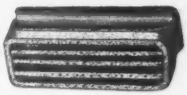

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Any person who is, or will become, a subscriber to the SIDEREAL MESSENGER during the months of September and October, 1885, can secure one of these pictures for $1.50. But few copies remain, and the original plate is destroyed. Address,

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CALENDAR.

Fall Term begins Wednesday, September 9, 1885,
Term Examinations, December 21st and 22d, 1885.
Winter Term begins Wednesday, January 6, and ends March 18, 1886.
Term Examinations, March 17th and 18th, 1886.
Spring Term begins Wednesday, March 31, and ends June 17, 1886.
Examinations to enter College, June 12 and 14, and Sept. 7, 1886.
Term Examinations, June 15 and 16, 1886.
Anniversary Exercises, June 14–17, 1886.
Exhibition at Art Room of work of Pupils in Drawing and Painting, June 14–17, 1885.
Wednesday, September 9, 1886, Fall Term begins.

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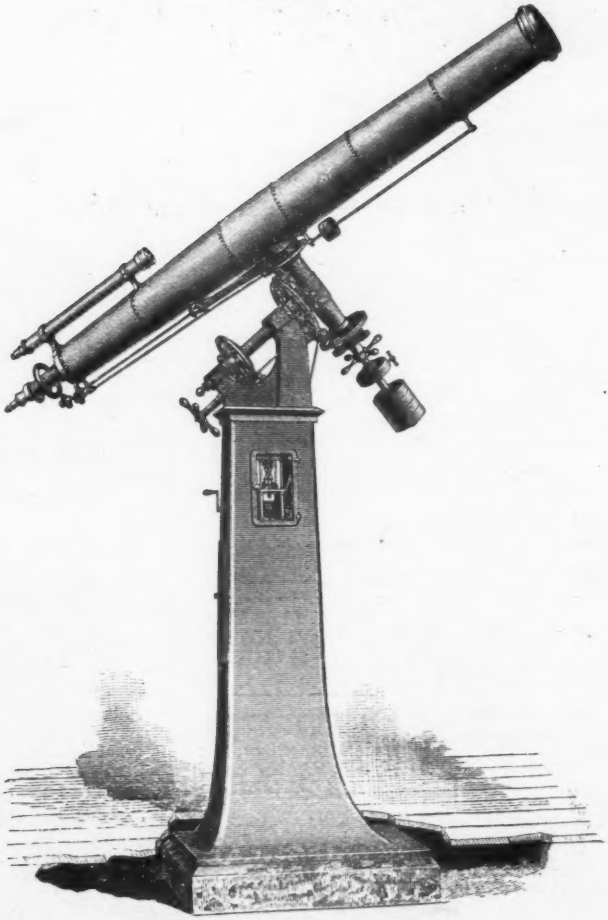

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